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THE HYDRODYNAMICS PERFORMANCE OF AQUACULTURE FISHING VESSEL IN VARIATION OF DEADRISE ANGLE AND SPONSON

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ABSTRACT

Tuna is one of the most potential commodities for export activities in Indonesia. To increase the number of tuna fish exports, fish farming is a more recommended method than fishing at sea. The vessel can be used for fish farming activities by completing the cultivation technology on the ship loading chamber. To gain profit other than fish cultivation, the ship can also be functioned as a means of tourist transportation. The problem is the excessive ship motion or sea keeping can increase the risk of live fish transported to quickly die. Therefore, this research will innovate to produce ship design as a means of live fish farming and can also be used as a means of tourism for tourists. This study focuses on aquaculture hull design innovations with hydrodynamic analysis, such as ship resistance and seakeeping, by using numerical methods. The hull design of the ship will be varied based on deadrise angle and sponson form. Numerically, Computational Fluid Dynamics (CFD) is used for the calculation of ship resistance, while 3D Diffraction Panel Method for seakeeping calculations. From the analysis, the Deadrise angle of 5 degrees is appropriate to be applied to aquaculture fishing vessel, because the cargo hold capacity is enough and the resistance is good. The L/B ratio of the sponson selected is 10.0 which the roll damping coefficient is the best in the variation.

KEYWORDS: Dead Rise Angle, Sponson, Computational Fluid Dynamic & Aquaculture Fishing Vessel

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Original Article

INTRODUCTION

The use of aquaculture fishing vessel is an innovation of sea transportation which has monohull. Initially, a ship is only used as transportation mode, but the function can be developed as the owner request nowadays. In the ship design & analysis, there are some considerations such as the maximum roll motion and effects of ship resistance which is the parameter accepted in all criteria. Along with the increasing needs of such fast vessels, also resulted the increasing number and capacity of shipyard production to be able to produce fast ships to meet the needs of existing market share. So far at the design stage, especially in small shipyards that produce fast boats, in determining the value of total resistance, the designers of fast ship generally use software applications that can briefly and easily give calculations, especially in determining the value of total resistance.

The ship hull having the streamline shape will give effect to the resistance produced so that it will improve the ship performance. The calculation of the ship's resistance value during operation is also important, because it affects the service speed. The choice of ship hull design will be very much affecting the ship operational, cargo hold capacity, and seaworthiness. The innovation of ship design can be carried out by changing the ship hull. Unfortunately, the calculation of ship resistance will provide more cost to be conducted the experimental test. By using numerical software, the total resistance of the ship can be easily calculated by modelling the ship. Beside this, method can save the cost and the time to complete the analysis can be reduced.

Figure 1:The Passenger Ship using Sponson

A shallow draft ship propensity has excessive motion especially for rolling and pitching motion which it needs an innovative design to reduce these motions. For aquaculture, fishing vessel, the excessive of these motions will affect the seasickness of passenger and fish. The passenger will not be comfortable, because the excessive motion and the fast rolling period will jeopardize the passenger condition. Fish loaded on the ship having excessive motion will be dead fast because the sloshing phenomena will cause the water impact in the cargo hold which the fish are located. Figure 1 shows the ship had been using sponson to reduce the rolling motion.

LITERATURE REVIEW

Some researchers had carried out the analysis of ship resistance by using some methods that were considered relevant at the time. The development of ship resistance theory is carried out continuously and perfected the existing literatures. Experiment test is always the most accurate method to prove the ship resistance analysis, because the phenomena occurred during the test can be captured and presented clearly by the researcher. In the example case about the effect of fouling and protective coating, the experimental method is only a sophisticated method that can be carried out. This technique is a mainstay to comply the problem about ship resistance.

The ship moving in water surface is always resolved into 2 (two) components, including the frictional and residual resistance. In the development of fishing vessel design, the deadrise angle is always a designer answer to reduce the ship resistance. A fishing vessel is a boat or ship used to catch fish in the sea, or in a lake or river. Many different kinds of vessels are used in commercial, artisanal and recreational fishing. [4] Furthermore, in term of its geometry or body plan, a fishing vessel is classified into round and chine types. Meanwhile, a chine type of fishing vessel is designed with high speed, because it has to reach the fishing ground as quickly as possible in order not to lose the right time to catch fish. Fishing vessel with multi-chine form is later discovered to be very efficient in term of lower resistance and hence saving time and fuel consumption.

In this case, the keel is inclined (equivalent to designing in trim) and a significantly larger propeller can be employed. This is similar to the approach used for conventional tugs and trawlers (a kind of fishing vessel). In the case of a larger vessel, such as a container ship, the draught amidships would be the design draught and the ship would ballast back to level keel if required by port draught limitations. There may be some increase in resistance with an inclined keel, but the indications are that the gains to be made from the increased propeller diameter are greater than the losses due to the increase in resistance. For example, the inclined keel investigation carried out and indicated an overall power saving of the order of 4%. The inclined keel is a feasible and practical proposition and these findings would suggest that the concept deserves further consideration. [2]

RESEARCH METHODS

Ship Resistance

A resistance test for a ship model follows the procedure originally proposed by William Froude. The (hydrodynamic) resistance of a ship is considered to be the sum of two independent main contributions: the viscous (or frictional) resistance, and the wave (or residual) resistance. [1] The former depends on the Reynolds number R_n, but is supposed to be unaffected by wave making; the latter depends on the Froude number F_n, but is supposed to be unaffected by viscosity. Therefore, the simplification can be shown in Equation 1.

$$C_t(F_n R_n) = C_w(F_n) + C_v(R_n) \tag{1}$$

The model is tested at an equal Froude number as the ship. In that case, the wave pattern is supposed to be geometrically similar and the wave resistance coefficient C_w equal for model and ship. However, the viscous resistance coefficient C_v differs between model and ship, and is dealt with separately. Thus the full-scale resistance coefficient can be shown in Equation 2. [5]

$$C_{ts} = C_{ws} + C_{vs} = C_{tm} - C_{vm} + C_{vs} \tag{2}$$

Where the subscripts *s* and *m* indicate ship and model, respectively. The essence now is how to estimate the difference in viscosity resistance coefficient between model and ship. In form-factor methods, which are mostly used today, the viscous resistance coefficient is supposed to be proportional to the frictional resistance coefficient of a flat plate at equal Reynolds number can be shown in Equation 3.[3] The 'form factor' $1+k$ is a constant that depends on the hull form but is supposed to be independent of the Reynolds and Froude numbers that can be shown in Equation 4.

$$C_v(R_n) = (1+k)C_{f0}(R_n) \tag{3}$$

$$C_{vm} - C_{vs} = (1+k)\left[C_{f0}(R_{nm}) - C_{f0}(R_{ns})\right] \tag{4}$$

Empirical expressions are available for the plate friction coefficient C_{f0} as a function of the Reynolds number; so-called plate friction lines, as shown in Figure.2. So if the form factor is known, the viscous resistance is known for both the model and the ship, and the ship resistance can be estimated from Equation 2. One approach to determine the form factor is to measure the total resistance at a low speed, at which the wave resistance can be neglected or is so small that it can be corrected for. $1+k$ then follows directly from the viscous resistance and C_{f0}. [6]

To the total ship resistance coefficient so found, a 'correlation allowance' *Ca* is added, an empirical coefficient, possibly from the institute's own data, that includes the effect of hull roughness and other effects. Clearly, this extrapolation procedure is fairly crude. The assumed scale effect is determined by a single hull form-dependent form factor and the plate friction line; the experimental determination of the form factor has often been less accurate, its equality for model and ship is an approximation, and wave/viscous interaction effects are disregarded. While overall the procedure works satisfactorily, we believe it is of interest to check and perhaps improve its different components, hoping to increase the accuracy of the power prediction. Today's computational tools should enable this. [7]

Roll Damping

A ship moving on the wave surface has always experienced the oscillatory motion. There are 2 (two) kind of

motion consisted of translation and rotation motion. There are 3 (three) translation motions such as 1) surging is a motion backwards and forwards in the direction of ship travel, 2) swaying is an athwart ship motion of the ship, and 3) heaving is a motion vertically up and down. There are also 3 (three) rotation motions such as 1) rolling is an angular motion about the longitudinal axis, 2) pitching is an angular motion about the transverse axis, and 3) yawing is an angular motion about the vertical axis. [10]

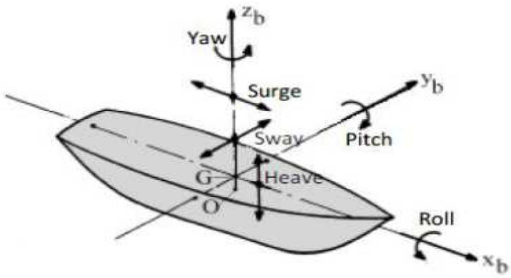

Figure 2: The Six-Degree of Freedom of Ship Motion

The damping coefficient acting on the ship during rolling motion can be caused by any combination of the following 1) wave generated, 2) water friction on the ship surface, 3) bilge keels, skeg, and other appendages, 4) resistance caused by between the ship and the air, 5) energy loss because of heat generated during the ship rolling motion, and 6) the last surface tension. [9]

$$b_n = \frac{\rho g^2}{\omega_e^3}\left(\frac{B_n}{2}\right)^2 \overline{A}_\phi^2 \tag{5}$$

$$\overline{A}_\phi^2 \frac{\zeta_a}{\phi_a\left(B_n/2\right)} \tag{6}$$

$$b = \int b_n d\xi \tag{7}$$

The effects due to causes 1, 2, and 3 are significant, whereas those due to causes 4, 5, and 6 are considered to be very small. As in the case of heaving and pitching motions, the damping coefficient is very important in rolling motion, especially because, the roll damping coefficient is relatively small and the magnification factor may reach a value between 5 and 10. The damping coefficient, due to wave making during the rolling motion, can also be calculated by the strip method. The damping coefficient per unit length is expressed as Equation 1, where $\overline{A}_\phi^2$ is defined as Equation 2.

By using the strip method, the total damping moment coefficient b is obtained from the expression of Equation 3. Since the frictional effect plays a significant role in roll-damping, the damping due to wave making alone may not be sufficiently accurate. In the first place, the bilge keel or other appendages fitted to a ship may contribute significantly to the total roll damping effect by the generation of eddies. Second, the ship speed is also a contributing factor in roll damping, which has been found to be as much as three times larger when the ship is in motion than when it is not under way. [8]

RESULTS AND ANALYSIS

Computational Fluid Dynamics (CFD) is one of the sophisticated methods to solve the fluid flow problem which the dependent variable such as velocity and pressure can be obviously represented by using this method. The first step to

start this simulation is by modeling the hull ship only which means that the ship construction does not need to be modeled. By using the approximation approach, the Navier-Stokes equation used to calculate the fluid flow problem can be simplified in order to be easy the solution. The fluid flowing throughout the ship model is assumed by the incompressible flow. The fluid properties are needed to be defined as the input variable in the Navier-Stokes equation. For the incompressible fluid flow, the density is assumed as the constant value because the pressure acting during the analysis does not greatly influence the change of density. In the field of Naval Architecture which is especially discussed about the hydrodynamic performances, the fluid affecting the ship motion behavior is assumed as the Newtonian Fluid which means that the viscous flow will contribute to produce the shear and normal stress during simulation. Figure 3 shows the body plan of the aquaculture, fishing vessel used to calculate the ship resistance and roll damping.

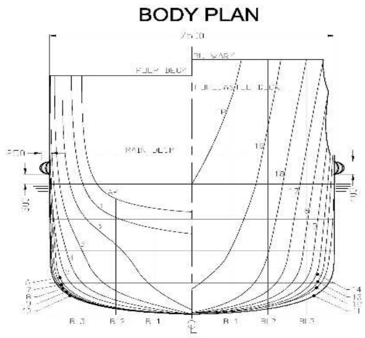

Figure 3:The Body Plan of Aquaculture Fishing Vessel Using Sponson in The Ship Side

Ship resistance analysis is proper to use the CFD method because the total resistance comprised viscous and wave making resistance can be obtained and showed clearly how the fluid flow behavior is. Figure 4 shows the ship model that is in a box as the towing tank. In order to get the optimum hull design, the ship hull is varied in 3 (three) models based on the deadrise angle. The Deadrise angles are 0, 5 and 10 degrees, which is used to the ship resistance analysis. The sponson is also varied in the ratio of Length (L) to Breadth (B). The ratios of L/B are 5.0, 7.5, and 10.0 which is used to the roll damping analysis. The sponson length is constant and the breadth is a variable so that the value can be changed.

Before the analysis is carried out, the determination of initial variable has to be conducted in order to start the simulation. This simulation is carried out by using the transient analysis, which the results of pressure and velocity are presented in time series. For the initial velocity of fluid flow, the constant value is applied during the simulation.

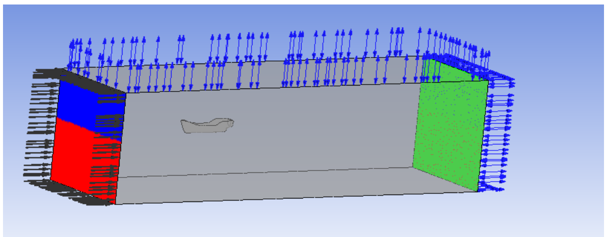

Figure 4: The Aquaculture Fishing Vessel Model in CFD Software

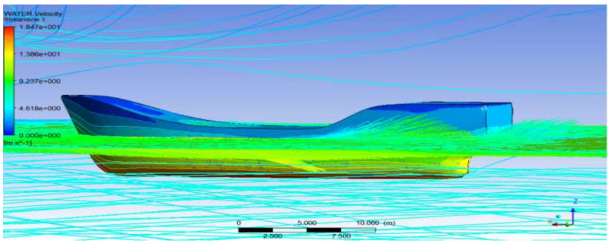

Figure 5: The Total Resistance of Ship by Using CFD Software

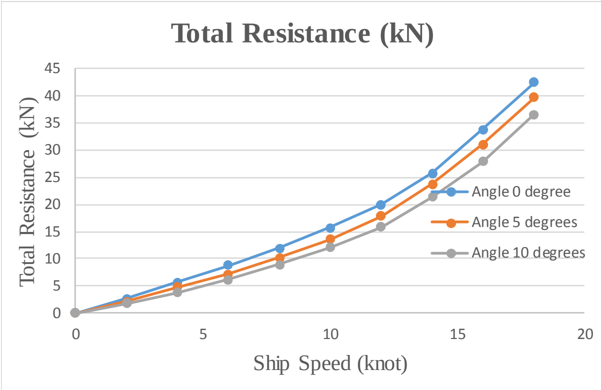

Figure 6:The Graph of Total Resistance to Ship Speed in Various of Deadrise Angle

Figure 5 shows the total resistance phenomena of ship which is presented by the viscous and wave making resistance during the simulation. The wave making resistance phenomena can be shown that there are waters jumping in the ship hull. Because this simulation is set by using two phases consisted of water and air, the wave making resistance of ship can be calculated. This resistance can be used to calculate the power of main engine needed later on. In order to obtain the minimum resistance, the deadrise angle is varied for this analysis.

Figure 6 explains the change of total resistance affected by the various of deadrise angle. From Figure 3, it can be concluded that the minimum resistance is at the angle of 10 degrees. The larger of deadrise angle will give the smaller of total resistance. If there is not any parameter considered, the deadrise angle selected is 10 degrees. However, the choice of Deadrise angle does not only consider the small resistance, but also the cargo hold capacity provides what payload that can be loaded. Table 1 shows the relation between cargo hold capacity and deadrise angle. Actually, the cargo hold capacity used to payload considers the owner requirement. Furthermore, this requirement can be definitely appropriated by the owner justification. In this case, the cargo hold capacity needed is not less than 170 tons, because the fish which is as payload are appointed in order to be considering the investment analysis. The deadrise angle selected is 5 degrees.

Table 1: The Relation of Cargo Hold Capacity

No.	Deadrise Angle (deg.)	Cargo Hold (m^3)	Presentase of Decrease (%)
1.	0	189.05	-
2.	5	174.63	7.63
3.	10	153.31	12.21

The excessive aquaculture ship motion of does definitely affect the seasickness of passenger and fish loaded. This ship is built from lighter material such as aluminum so that the ship draft is very small. This condition will be a risk that the ship does experience the excessive roll motion when applied a wave from the beam sea. In order to avoid the accident caused by the wave from the ship side, the sponson can be used to minimize the effect of roll motion. For this analysis, the

sponson dimension is varied by the ratio of Length (L) to Breadth (B). The L/B ratios are 5.0, 7.5, and 10.0 which the length is constant and the breadth is varied. The excessive rolling ship motion can be measured by the damping coefficient of the ship. To calculate the damping coefficient of the ship, the CFD software can be used which the set of simulation is definitely different with the ship resistance simulation. Table 2 to 4 show the rolling motion of the aquaculture, fishing vessel by using the two dimensional analysis.

Table 2: The Rolling Ship Motion at the Deadrise Angle of 0 Degree

No.	$\delta\theta$ (deg)	θ (deg)	θ_m (deg)
1.	0.0	12.4	0.0
2.	2.0	10.4	11.4
3.	1.8	8.6	9.5
4.	1.8	6.8	7.7
5.	1.3	5.5	6.1
6.	1.4	4.1	4.8
7.	1.2	2.9	3.5
8.	0.8	2.1	2.5

Table 3: Rolling Ship Motion at the Deadrise Angle of 5 Degrees

No.	$\delta\theta$ (deg)	θ (deg)	θ_m (deg)
1.	0.0	11.8	0.0
2.	2.0	9.8	10.8
3.	1.7	8.1	8.9
4.	1.6	6.5	7.3
5.	1.6	4.9	5.7
6.	1.2	3.7	4.3
7.	0.8	2.9	3.3
8.	0.8	2.1	2.5

Table 4: The Rolling Ship Motion at The Deadrise Angle of 10 Degrees

No.	$\delta\theta$ (deg)	θ (deg)	θ_m (deg)
1.	0.0	11.1	0.0
2.	2.0	9.1	10.1
3.	1.7	7.4	8.2
4.	1.6	5.8	6.6
5.	1.5	4.3	5.1
6.	1.1	3.2	3.8
7.	0.7	2.5	2.9
8.	0.8	1.7	2.1

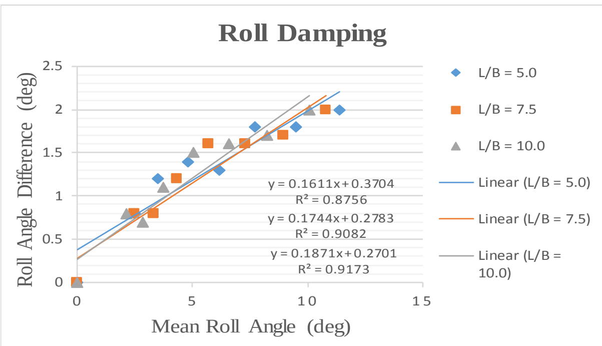

Figure 2. The Plot of Roll Degree in Various of the L/B Ratio

Roll damping coefficient is a non-dimensional parameter used to calculate the behavior of rolling ship motion.

This simulation is definitely carried out at the regular wave so that the change of roll degree is regularly different in time series.

Table 2 can be explained that the initial roll degree is 12.4 and this roll values decrease which the roll damping affects it. Table 3 and 4 can be described that the initial roll degrees are 11.8 and 11.1 for the deadrise angle of 5 and 10 degrees respectively. This value is measured in 8 (eight) cycles. Table 3 and 4 have same pattern with Table 2 which the roll degrees decrease in time series. The larger of L/B ratio will decrease the response of roll motion. The initial change of roll degree is larger than the other roll degrees. Theoretically, the roll motion is not only affected by the roll damping, but also the restoring moment, which the sponson dimension influences the roll degree values.

Figure 7 can explain the roll angle difference to the mean roll angle. From this table, the greatest roll damping is at the Deadrise angle of 10 Degrees. It can be shown that the roll Damping relates to the Slope or gradient of the graph. The greater gradient or Slope graph will produce the greater of roll damping. This graph can be Obtained from the linear Regression because there are Many points which between one point and others is not in a line, so that the regression method Is very useful to Obtain the gradient of graph.

CONCLUSIONS

- There is a maximum point of C_L to the various of angle of attack which is a stall phenomenon occurred in the angle of 20 degrees in each of NACA foil type.
- NACA 4712 has the greatest value of C_L which the magnitude is 0.49 meaning that the force is 49% from the multiple between the velocity pressure and the surface applied the force.
- The form factor of NACA 4712 is smaller when the chord length is longer. It occurs because the chamber of the chord length varied is same in 0.5 m. The foil shape does close to the slender form which the drag force decreases.

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REFERENCES

1. *Hoke, C. M., Young, J., Lai, J. C. S.(2015). Effects of time-varying camber deformation on flapping foil propulsion and power extraction. Journal of Fluids and Structures. Volume 56. July 2015. Pages 152 – 176.*
2. *Hoerner, S. F.(1965). Fluid-dynamics drag. Published by the author. New York*
3. *Lakshman, A., and Sivakumar, R.(2014)., CFD Analysis of Double Ramp in Hypersonic Flows. International Journal of Applied Engineering Research. Volume 9. Number 26. Pages 8883 – 8886.*
4. *Make, M., and Vaz, G.(2015). Analyzing scaling effects on offshore wind turbines using CFD. Renewable Energy. Volume 83. November 2015. Pages 1326 – 1340.*
5. *Putranto, T., Sulisetyono, A. (2017). Lift-Drag Coefficient and Form Factor Analyses of Hydrofoil due to The Shape and Angle of Attack. International Journal of Applied Engineering Research. Volume 12. Number 21. Pages 11152 – 11156. Research India Publication.*

6. *Putranto, T., Suastika, K., and Gunanta, J (2017). Intact Stability Analysis of Crew Boat with Variation of Deadrise Angle. IPTEK Journal of Proceedings Series. Volume 2. Pages 124 – 127.*
7. *Putranto, T., and Sulisetyono, A (2015). Analisa Numerik Gerakan dan Kekuatan Kapal Akibat Beban Slamming Pada Kapal Perang Tipe Corvette. Jurnal KAPAL Volume 12. Number 3. Pages 158 – 164.*
8. *Snigdha Mandapudi et al.,, CFD Simulation of Flow Past Wing Body Junction: A 3-D ApproachDeserts, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 7, Issue 4, July - August 2017, pp. 341-350*
9. *Ramesha, D. K., Kumarswamy, N. S., Kishore, H. N., Vidya S., and Premkumara, G (2011). Numerical Simulation of Cavitating Flow over Oscillating Hydrofoils. International Journal of Applied Engineering Research. Volume 6. Number 10. Pages 1273 – 1283.*
10. *Shinde, S. B., and Sivakumar, R (2014). CFD Analysis of Fluid Flow Around An Elliptic Cylinder. International Journal of Applied Engineering Research. Volume 9. Number 26. Pages 8887 – 8890.*
11. *Wu Q., Wang, Y., Wang, G (2017) Experimental Investigation of Cavitating Flow-Induced Vibration of Hydrofoils. Ocean Engineering. Volume 144. Pages 50 – 60.*